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Quarterly Report

No. 8

*LIFAC Sorbent Injection
Desulfurization
Demonstration Project*

Presented By

LIFAC NORTH AMERICA, INC.

A Joint Venture Between

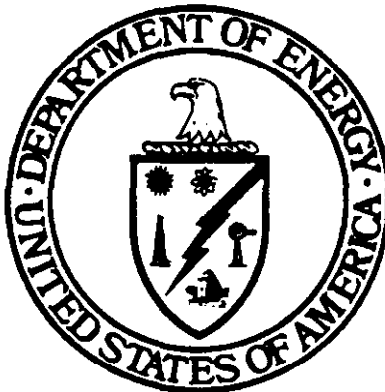
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Presented To



U.S. Department of Energy

Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania 15236

July - September 1992

**LIFAC SORBENT INJECTION
DESULFURIZATION DEMONSTRATION PROJECT**

**QUARTERLY REPORT NO. 8
JULY - SEPTEMBER 1992**

**Submitted to

U. S. DEPARTMENT OF ENERGY**

**by
LIFAC NORTH AMERICA**

LIFAC Sorbent Injection Desulfurization Demonstration Project

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INTRODUCTION

In December 1990, the U.S. Department of Energy selected 13 projects for funding under the Federal Clean Coal Technology Program (Round III). One of the projects selected was the project sponsored by LIFAC North America, (LIFAC NA), titled "LIFAC Sorbent Injection Desulfurization Demonstration Project." The host site for this \$22 million, three-phase project is Richmond Power and Light's Whitewater Valley Unit No. 2 in Richmond, Indiana. The LIFAC technology uses upper-furnace limestone injection with patented humidification of the flue gas to remove 75-85% of the sulfur dioxide (SO₂) in the flue gas.

In November 1990, after a ten (10) month negotiation period, LIFAC NA and the U.S. DOE entered into a Cooperative Agreement for the design, construction, and demonstration of the LIFAC system. This report is the eighth Technical Progress Report covering the period July 1, 1992 through the end of September 1992. Due to the power plant's planned outage schedule, and the time needed for engineering, design and procurement of critical equipment, DOE and LIFAC NA agreed to execute the Design Phase of the project in August 1990, with DOE funding contingent upon final signing of the Cooperative Agreement.

BACKGROUND

Project Team

The LIFAC demonstration at Whitewater Valley Unit No. 2 is being conducted by LIFAC North America, a joint venture partnership between:

- ICF Kaiser Engineers - A U.S. company based in Oakland, California, and a subsidiary of ICF International (ICF) based in Fairfax, Virginia.
- Tampella Power Corp. - A U.S. subsidiary of a large diversified international company, Tampella Corp., based in Tampere, Finland and the original developer of the LIFAC technology.

LIFAC NA is responsible for the overall administration of the project and for providing the 50 percent matching funds. Except for project administration, however, most of the actual work is being performed by the

two parent firms under service agreements with LIFAC NA. Both parent firms work closely with Richmond Power and Light and the other project team members, including ICF Resources, the Electric Power Research Institute (EPRI), Indiana Corporation for Science and Technology (ICS&T), and Black Beauty Coal Company. LIFAC NA is having ICF Kaiser Engineers manage the demonstration project out of its Pittsburgh office, which provides excellent access to the DOE representatives of the Pittsburgh Energy Technology Center. Figure 1 shows the management structure being used throughout the three phases of the project.

LIFAC NA administers the project through a Management Committee that decides the overall policies, budgets, and schedules. All funding sources, invoicing, and information flows to LIFAC NA where the managing partners ensure that the project, funding and expenditures are consistent and in-line with the established policies, budgets, schedules and procedures.

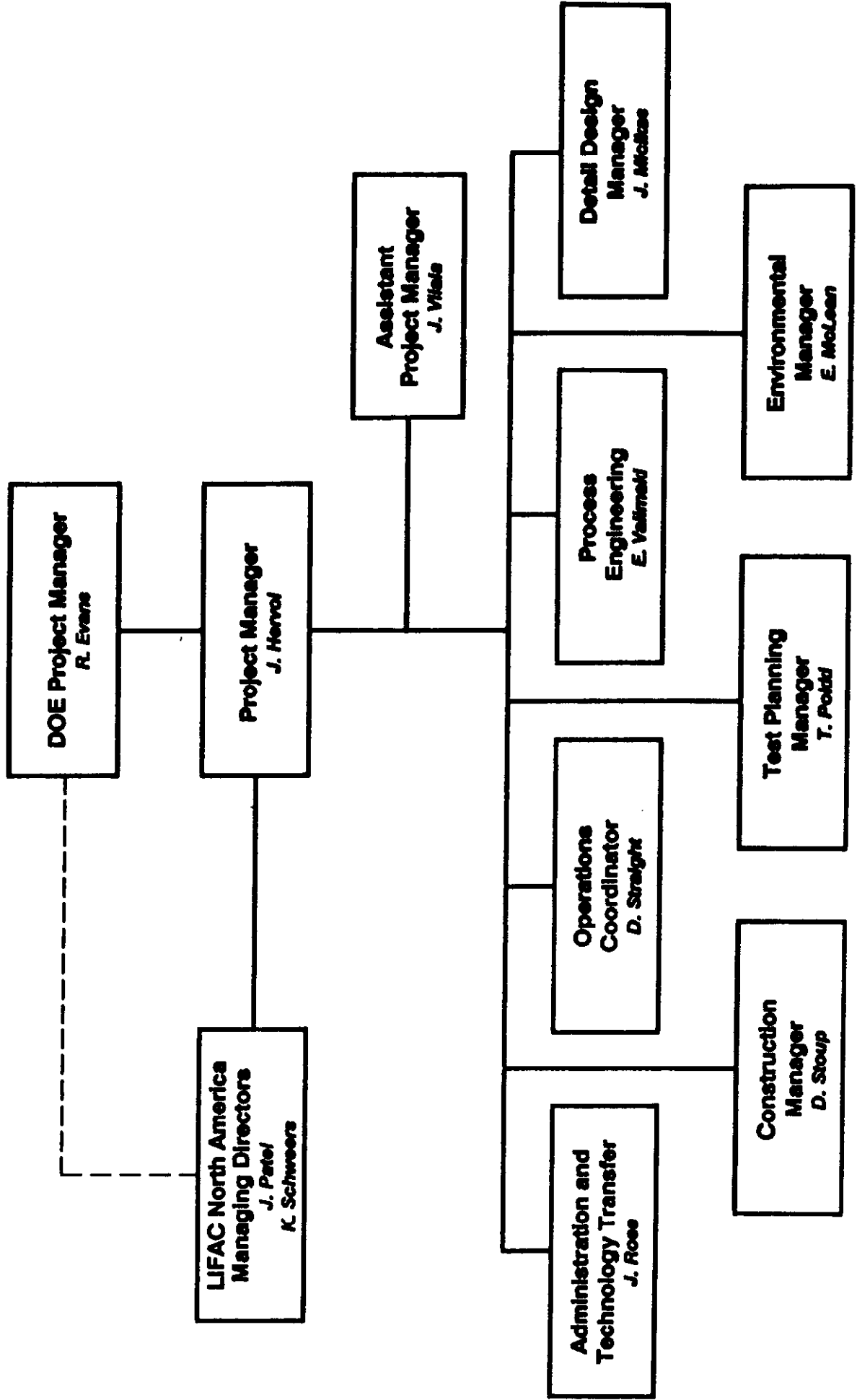
Process Development

In 1983, Finland enacted acid rain legislation which applied limits on SO₂ emissions sufficient to require that flue gas desulfurization systems have the capability to remove about eighty percent (80%) of the sulfur dioxide in the flue gas. This level could be met by conventional scrubbers, but could not be met by then available sorbent injection technology. Therefore, Tampella began developing an alternative system which resulted in the LIFAC process.

Initially, development included laboratory-scale and pilot-plant tests. Full-scale limestone injection tests were conducted at Tampella's Inkeroinen facility, a 160 MW coal-fired boiler using high-ash, low-sulfur Polish coal. At Ca:S ratios of 3:1, sulfur removal was less than 50%. Better results could have been attained using lime, but was rejected because the cost of lime is much higher than that of limestone.

In-house investigations by Tampella led to an alternative approach involving humidification in a separate vertical chamber which became known as the LIFAC Process. In cooperation with Pohjolan Voima Oy, a Finnish utility, Tampella installed a full-scale limestone injection facility on

Project Organization



a 220 MW coal-fired boiler located at Kristiinankaupunki. At this facility, a slipstream (5000 SCFM) containing the calcined limestone was used to test a small-scale activation reactor (2.5 MW) in which the gas was humidified. Reactor residence times of 3 to 12 seconds resulted in SO₂ removal rates up to 84%. Additional LIFAC pilot-scale tests were conducted at the 8 MW (thermal) level at the Neste Kulloo combustion laboratory to develop the relationships between the important operating and design parameters. Polish low-sulfur coal was burned to achieve 84% SO₂ removal.

In 1986, full-scale testing of LIFAC was conducted at Imatran Voima's Inkoo power plant on a 250 MW utility boiler. An activation chamber was built to treat a flue gas stream representing about 70 MW. Even though the boiler was 250 MW, the 70 MW stream represented about one-half of the flue gas feeding one of the plant's two ESP's (i.e., each ESP receives a 125 MW gas stream). This boiler used a 1.5% sulfur coal and sulfur removal was initially 61%. By late 1987, SO₂ removal rates had improved to 76%. In 1988, a LIFAC activation reactor was added to treat an additional 125 MW -- i.e., an entire flue gas/ESP stream-worth of flue gas from this same boiler. This newer activation reactor is achieving 75-80% SO₂ removal with Ca:S ratios between 2:1 and 2.5:1. In 1988, the first tests using high-sulfur U.S. coals were run at the pilot scale at the Neste Kulloo Research Center, using a Pittsburgh No. 8 coal containing 3% sulfur. SO₂ removal rates of 77% were achieved at a Ca:S ratio of 2:1.

This LIFAC demonstration project will be conducted on a 60 MW boiler burning high-sulfur U.S. coals to demonstrate the commercial application of the LIFAC process to U.S. utilities.

Process Description

LIFAC combines upper-furnace limestone injection followed by post-furnace humidification in an activation reactor located between the air preheater and the ESP. The process produces a dry and stable waste product that is partially removed from the bottom of the activation reactor and partially removed at the ESP.

Finely pulverized limestone is pneumatically conveyed and injected into the upper part of the boiler. Since the temperatures at the point of injection are in the range of 1800-2000° F, the limestone (CaCO_3) decomposes to form lime (CaO). As the lime passes through the furnace, initial desulfurization reactions take place. A portion of the SO_2 reacts with the CaO to form calcium sulfite (CaSO_3), part of which then oxidizes to form calcium sulfate (CaSO_4). Essentially all of the sulfur trioxide (SO_3) reacts with the CaO to form CaSO_4 .

The flue gas and unreacted lime exit the boiler and pass through the air preheater. On leaving the air preheater, the gas/lime mixture is directed to the patented LIFAC activation reactor. In the reactor, additional sulfur dioxide capture occurs after the flue gas is humidified with a water spray. Humidification converts lime (CaO) to hydrated lime, Ca(OH)_2 , which enhances further SO_2 removal. The activation reactor is designed to allow time for effective humidification of the flue gas, activation of the lime, and reaction of the SO_2 with the sorbent. All the water droplets evaporate before the flue gas leaves the activation reactor. The activation reactor is also designed specifically to minimize the potential for solids build-up on the walls of the chamber. The net effect is that at a Ca:S ratio in the range of 2:1 to 2.5:1, 70-80% of the SO_2 is removed from the flue gas.

The flue gas leaving the activation reactor then enters the existing ESP where the spent sorbent and fly ash are removed from the flue gas and sent to the disposal facilities. ESP effectiveness is also enhanced by the humidification of the flue gas. The solids collected by the ESP consist of fly ash, CaCO_3 , Ca(OH)_2 , CaO , CaSO_4 , and CaSO_3 . To improve utilization of the calcium, and increase SO_2 reduction to between 75 and 85%, a portion of the spent sorbent collected in the bottom of the activation reactor and/or in the ESP hoppers is recycled back into the ductwork just ahead of the activation reactor.

Process Advantages

The LIFAC technology has similarities to other sorbent injection technologies using humidification, but employs a unique patented vertical reaction chamber located down-stream of the boiler to facilitate and

control the sulfur capture and other chemical reactions. This chamber improves the overall reaction efficiency enough to allow the use of pulverized limestone rather than more expensive reagents such as lime which are often used to increase the efficiency of other sorbent injection processes.

Sorbent injection is a potentially important alternative to conventional wet lime and limestone scrubbing, and this project is another effort to test alternative sorbent injection approaches. In comparison to wet systems, LIFAC, with recirculation of the sorbent, removes less sulfur dioxide - 75-85% relative to 90% or greater for conventional scrubbers - and requires more reagent material. However, if the demonstration is successful, LIFAC will offer these important advantages over wet scrubbing systems:

- LIFAC is relatively easy to retrofit to an existing boiler and requires less area than conventional wet FGD systems.
- LIFAC is less expensive to install than conventional wet FGD processes.
- LIFAC's overall costs measured on a dollar-per-ton SO₂ removed basis are less, an important advantage in a regulatory regime with trading of emission allocations.
- LIFAC produces a dry, readily disposable waste by-product versus a wet product.
- LIFAC is relatively simple to operate.

HOST SITE DESCRIPTION

The site for the LIFAC demonstration is Richmond Power and Light's Whitewater Valley 2 pulverized coal-fired power station (60 MW), located in Richmond, Indiana. Whitewater Valley 2, which began service in 1971, is a Combustion Engineering tangentially-fired boiler which uses high-sulfur bituminous coal from Western Indiana. Actual power generation produced by the unit approaches 65 megawatts. As such, it is one of the

smallest existing, tangentially-fired units in the United States. The furnace is 26-feet, 11-inches deep and 24-feet, 8-inches wide. It has a primary and secondary superheater. Tube sizes and spacings are designed to achieve the highest possible heat-transfer rates with the least potential for gas-side fouling. The unit also has an inherent low draft-loss characteristic because of the lack of gas turns. At full load 540,000 lbs/hr. of steam are generated. The heat input at rated capacity is 651×10^6 Btu per hour. The design superheater outlet pressure and temperature are 1320 psi at 955°F. The unit has a horizontal shaft basket-type air preheater. The temperature leaving the economizer is about 645°F, while the stack gas temperature is about 316°F. The balanced-draft unit has 12 burners.

In 1980 the unit was fitted and fully optimized with a state-of-the-art Low-NO_x Concentric Firing System (LNCFS). The LNCFS represents a very cost effective means of reducing NO_x emissions in comparison with other retrofit possibilities. The system works on the principal of directing secondary air along the sides of the furnace and creating a fuel rich zone in the center of the furnace. With the LNCFS, the excess air can be maintained below 20 percent. Additionally, the installation reduces ash accumulation on the furnace walls increasing heat absorption and reducing attemperation requirements. With the LNCFS, each corner of the furnace has a tangential windbox consisting of three coal compartments and four auxiliary air compartments. At full load with all three 593 RB pulverizers operating, primary transport air from the pulverizers amounts to 23 percent of the total combustion air. Pulverizer capacity is 26,400 lbs/hr. with 52 grind coal and 70 percent minus 200 mesh.

Whitewater Valley 2 has a Lodge Cottrell cold side precipitator which was erected with the boiler. The precipitator treats 227,000 actual cubic feet per minute of 316°F flue gas with 45,000 square feet of collection area. The unit has two mechanical fields and four electrical fields and achieves 99 percent removal efficiency (from 3.9 gr/ft³ to 0.04 gr/ft³). The ESP performance was optimized by Lodge Cottrell when Richmond Power and Light purchased new controllers in 1985.

Whitewater Valley Unit 2's overall efficiency of 87.47 percent at full load has shown little variation over the years. The unit's average heat rate is 10,280 Btu/Kwh. At 60 percent of full load, the unit's efficiency increases to 88.17 percent. The unit uses approximately 0.935 pounds of coal per Kwh and generates 8.51 pounds of steam per Kwh.

The primary emissions monitored at the station are SO₂ and opacity. SO₂ emissions are calculated based on the coal analysis and are limited to 6 lbs/MBtu. Opacity is monitored using an in-situ meter at the stack and is currently limited to 40 percent. Current SO₂ emissions for the unit are approximately 4 lbs/Mbtu, while opacity at full load ranges from 15 to 20 percent. Opacity at low load (40MW) ranges from 3 to 5 percent. Limited testing was conducted in November of 1986 for NO_x emissions. Results from the test work indicated that NO_x emissions averaged 0.65 lbs/MBtu.

Whitewater Valley 2 has several important qualities as a LIFAC demonstration site. One of these is that Whitewater Valley 2 was the site of a prior joint EPA/EPRI demonstration of LIMB sorbent injection technology. Much of the sorbent injection equipment remains on site and is being used in the LIFAC demonstration. Another advantage of the site is that Whitewater Valley 2 was a challenging candidate for a retrofit due to the cramped conditions at the site. The plant is thus typical of many U.S. power plants which are potential sites for application of LIFAC. In addition, the Whitewater Valley 2 boiler is small relative to its capacity; hence, it has high-temperature profiles relative to other boilers. This situation requires sorbent injection at higher points in the furnace to minimize deadburning of the reagent, but it decreases residence times needed for sulfur removal. Whitewater Valley 2 will show LIFAC's performance under operational conditions most typical of U.S. power plants. The project will demonstrate LIFAC on high-sulfur U.S. coals and is a logical extension of the Finnish demonstration work and important for LIFAC's commercial success in the U.S.

PROJECT SCHEDULE

To demonstrate the technical viability of the LIFAC process to economically reduce sulfur emissions from the Whitewater Valley Unit No. 2, LIFAC NA is conducting a three-phase project.

Phase I: Design

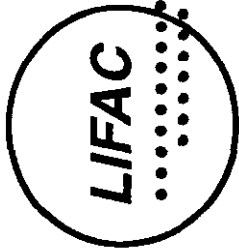
Phase IIA: Long Lead Procurement

Phase IIB: Construction

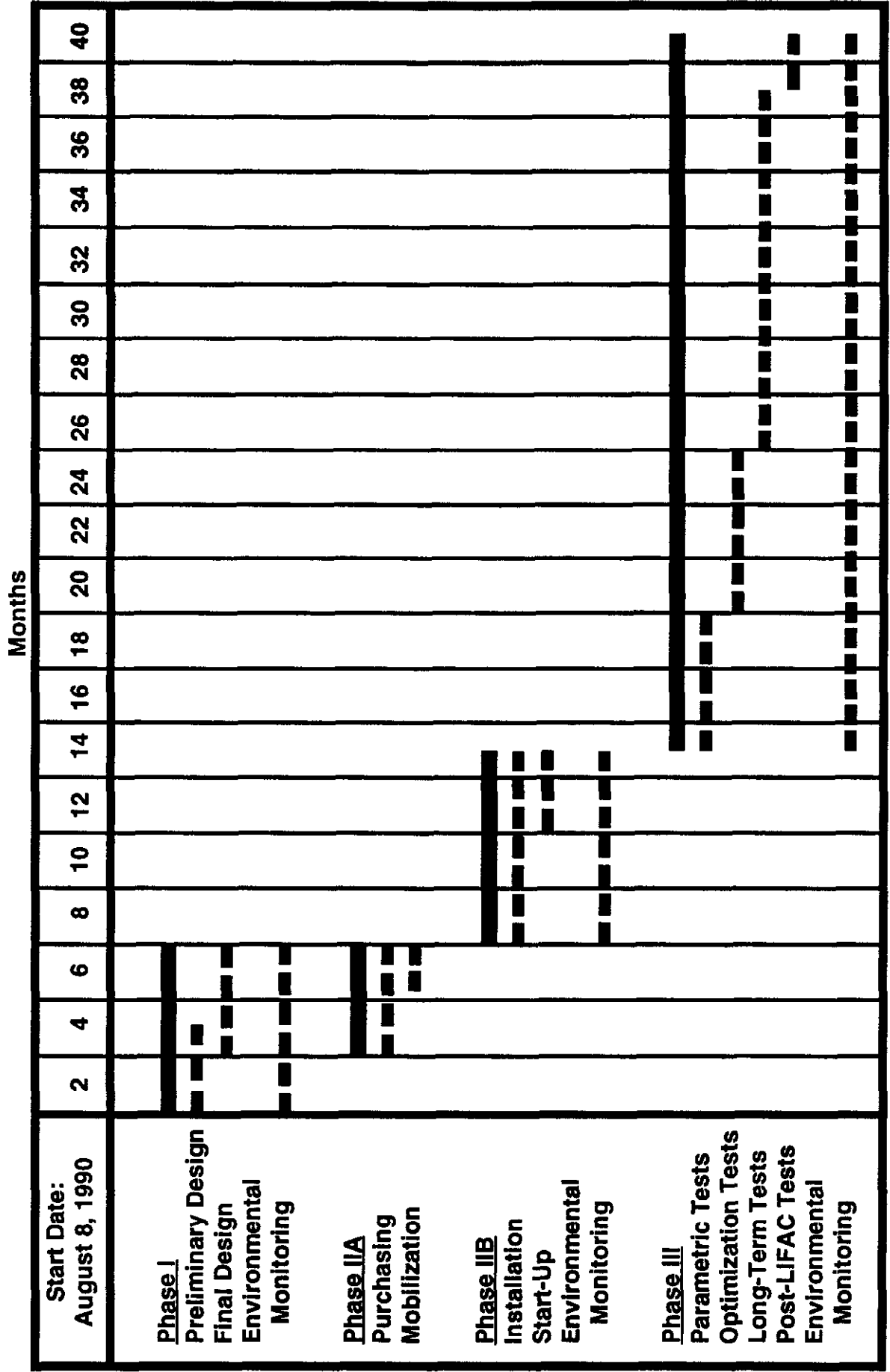
Phase III: Operations

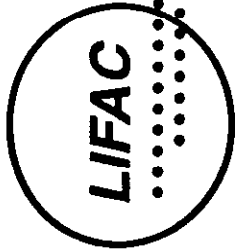
Except Phase IIA, each phase is comprised of three (3) tasks, a management and administration task, a technical task and an environmental task. The design phase began on August 8, 1990 and was scheduled to last six (6) months. Phase IIA, long lead procurement, overlaps the design phase and was expected to require about four (4) months to complete. The construction phase was then to continue for another seven (7) months, while the operations phase was scheduled to last about twenty-six (26) months. Figure 2 shows the original estimated project schedule which is based on a August 8, 1990 start date and a planned outage of Whitewater Valley 2 during March 1991.

It is during this outage that all the tie-ins and modifications to existing Unit No. 2 equipment were made. This required that the construction phase begin in early February, 1991 -- construction was to be completed by the end of August 1991. Operations and testing were to begin in September 1991 and continue for 26 months. However, during previous reporting periods, the project encountered delays in receiving its construction permit. These delays, along with some design changes, and an approved expansion in project scope required that the Design Phase be extended by about eleven months. Therefore, construction was not completed until early June 1992. This represents a nine-month extension in the overall schedule. During this reporting period, problems were encountered during startup and commissioning of some of the LIFAC components and systems. These problems required the parametric tests to be delayed until next quarter which subsequently required adjustments in the entire testing schedule. These delays, however, will not impact the overall duration of the Operations Phase. Figure 3 shows the revised

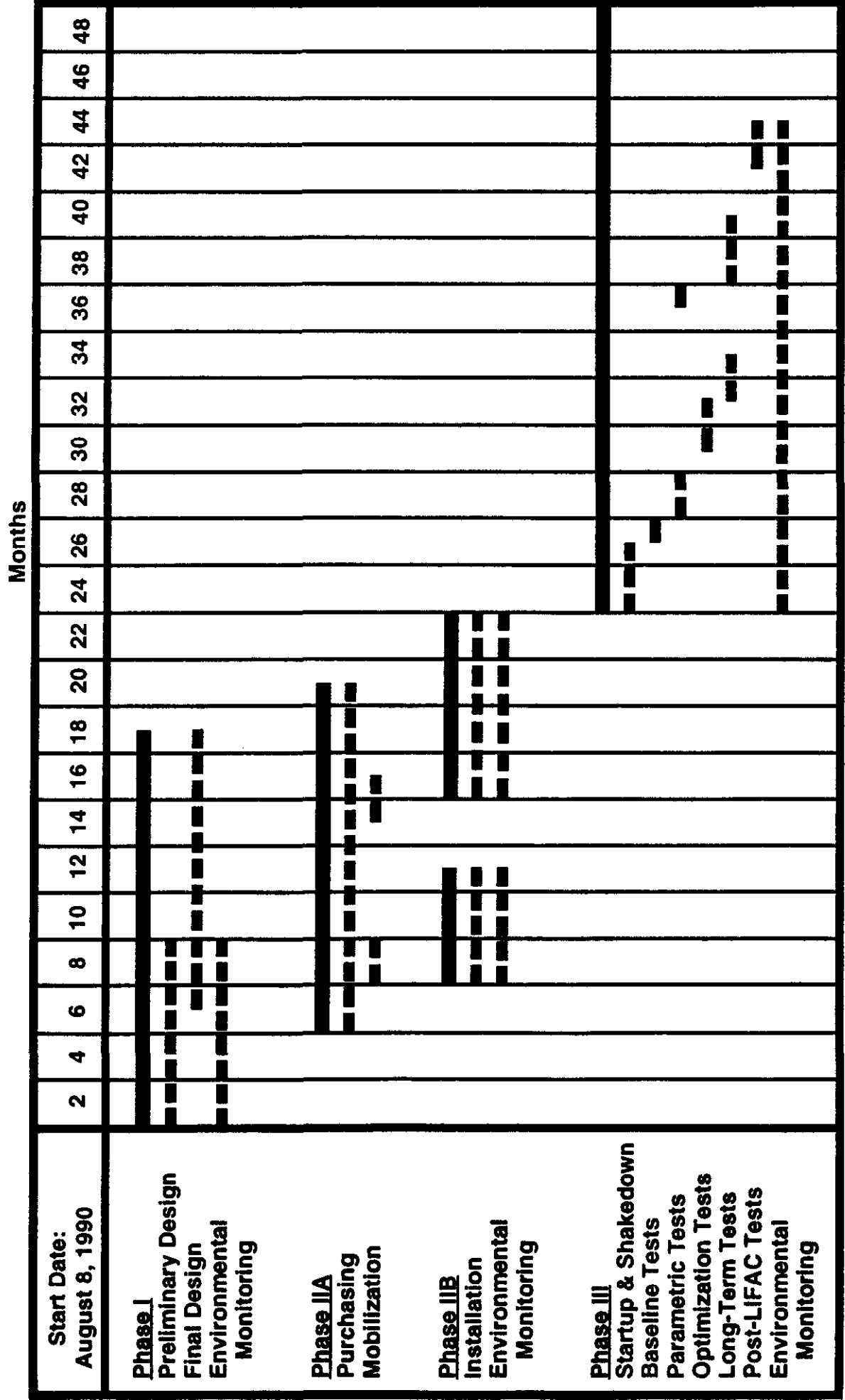


LIFAC Demonstration Original Project Schedule





LIFAC Demonstration Current Project Schedule



project schedule including the adjustments made in the testing schedule. Total project duration is now 48 months.

TECHNICAL PROGRESS

The work performed during this period (July - September 1992) was consistent with the revised Statement of Work (Scope Increase) and the approved schedule change contained in the Cooperative Agreement. During this period, emphasis was placed on startup and commissioning activities and baseline testing. Work was conducted under the three tasks comprising the Operations Phase. Following is a summary of the work performed under these tasks.

Project Management (WBS 1.3.1)

During the July through September 1992 period, management efforts and achievements included:

- **LIFAC Management Committee Meeting #11** - During the prior quarter, April through June 1992, the LIFAC management committee held three formal meetings, including one at the end of the period. These meetings addressed numerous issues related to the conclusion of Period I and the transition to Period II.

During this quarter, the LIFAC management committee held its eleventh formal management committee meeting on September 14, 1992 at the Tampella Power offices in Atlanta, Georgia. The agenda of this meeting included:

- Project schedule for the operations phase and potential for delay. The committee wanted to meet at the site after the ID fan variable frequency drive was installed during the Fall outage at Whitewater Valley Unit #2.
- Period II labor hours by task, and the appropriateness of budgeted staffing levels.

- The committee heard reports on regulatory and permitting developments, especially the future review of the project by EPA Region V.
- The committee also heard reports related to fulfillment of the DOE Cooperative agreement including the numerous reports required at the end of budget Period I, and those required at the beginning of Period II.
- Subcontractor authorization.
- Funding agreements especially EPRI.
- Tampella and ICF Kaiser funding contributions.
- Technology transfer including: (1) conferences, (2) papers, (3) meetings with individual utilities, (4) presentation material, (5) publicity, (6) coordination with vendors of related auxiliary systems, and (7) anticipation of concerns of potential clients.

The project supplemented this formal meeting with frequent informal consultations. Other important management activities included:

- **Joint LIFAC NA/DOE Cooperation** - During this period, DOE conducted a second review of the management of the LIFAC project. For this period, LIFAC NA worked to continue to implement the Cooperative Agreement's management, administrative and technical provisions including DOE reporting and administrative requirements:
 - The project reviewed progress on the numerous reports associated with the completion of Period I and the commencement of Period II including the Project Evaluation Plan, Project Evaluation

Report, Test Plan, Startup Plan, Environmental Monitoring Plan (EMP), Continuation Application, and Design Report.

- LIFAC NA provided to DOE selected required financial, project and cost reports including: (1) monthly technical progress, (2) cost management, and (3) federal assistance management summary reports.
- LIFAC NA sent invoices to DOE during the period consistent with DOE requirements that the project report invoiced costs on a phase-by-phase basis.
- **Regulatory** - Overall, in previous periods, the project resolved nearly all regulatory problems (e.g. receipt of the solid waste disposal letter from IDEM). However, due to the importance of this area, the LIFAC Management Committee continued to manage/oversee, and in some cases, directly participate (e.g. meeting with regulatory attorneys) in the permitting and approvals process. The environmental regulatory situation, discussed further elsewhere, is summarized here.

The principal outstanding issue during the period related to TSP emissions. RP&L and LIFAC NA were in contact with EPA Region V with regard to TSP emissions. LIFAC NA closely monitored developments in this area.

- **Funding Agreements** - LIFAC NA continued efforts to negotiate and finalize arrangements for participation/funding of other project participants:
 - Electric Power Research Institute - LIFAC NA project managers conferred with representatives of EPRI to discuss EPRI funding. More

information on funding and technical assistance is expected in the next reporting period.

- Indiana Corporation for Science and Technology (CST) - LIFAC NA received all remaining funding during the prior period; no more funding is anticipated at this time.
- Black Beauty Coal Company - In August, Black Beauty agreed to provide all the test coal needed for the demonstration project. Specifically, it will provide three different test coals as follows:

Coal No. 1 - 49,500 tons @ 2.3% to 2.6% sulfur

Coal No. 2 - 3,400 tons @ 3.3% to 3.6% sulfur

Coal No. 3 - 17,200 tons @ 1.3% to 1.6% sulfur

Black Beauty has agreed to cost-share in these coal deliveries. Its estimated contribution is about \$378,750. Black Beauty's first delivery was made in July for the Baseline Tests.

- **Technology Transfer Activities** - During the quarter, LIFAC NA and DOE jointly presented papers at the Pittsburgh coal conference held in Pittsburgh and the Clean Coal conference held in Cleveland.

Testing and Data Analysis (WBS 1.3.2)

During this period, the Test Plan was initiated and the following activities were performed:

- **Baseline Testing** - The baseline testing portion of the Test Plan was completed from August 26 to September 2. This consisted of evaluating the host boiler performance without LIFAC in operation. This was accomplished by fulfillment of the following main tasks:

- A baseline coal of very consistent sulfur content was burned throughout the baseline tests. Sulfur content was confirmed by host site and outside laboratory analysis.
- Ash samples were taken at the air preheater hopper and the ESP hoppers. These samples were sent to outside laboratories for content analysis.
- SO₂ measurements were taken after the boiler for comparison with coal feed analysis. In-situ and portable analyzers provided this information.
- A temperature profile was generated at the injection level in the furnace through the use of a portable suction pyrometer.
- Excess O₂ was measured before and after the air preheater. This was done with in-situ and portable analyzers.

Other boiler performance measurements were taken in addition to these as outlined in the Test Plan. Data collection occurred during three different boiler load periods to characterize the boiler over its normal operating range.

- **Baseline Test Report** - Data obtained during the baseline tests are being processed and analyzed for incorporation into the Baseline Test Report. After receipt of coal and ash sample analyses from outside laboratories, the report will be completed and submitted to DOE for review and comment.

Also during this period, emphasis was placed on startup and commissioning activities in the three main areas.

- **Limestone Handling and Storage Area** - From July 1 to the end of September, startup progressed well in the limestone area. Work included:

- Installation of a new limestone transport blower to replace one of the existing blowers.
 - Completion of all punch list items.
 - Mechanical and electrical acceptance of all new and used equipment in the area.
 - Startup and calibration of all new and existing instrumentation.
 - Receipt of the first limestone delivery. Pulverized limestone was loaded into the new silo and successfully transferred to the feed silo, and pneumatically conveyed to the boiler injection nozzles.
- **Boilerhouse and ESP area** - During this period, all mechanical and electrical systems were checked, calibrated and tested. A few problems have occurred that will require additional work during the plant outage next period. These problems were:
 - The flue gas bypass damper would not close 100%. This caused a shortcircuiting of 10% to 15% of the flue gas around the activation reactor. This prevents maximum SO₂ reductions and prevented accurate analyses (SO₂) of the flue gas after the reactor.
 - The on-line flue gas analyzers experienced excessive wear in their original positions in the ductwork. The analyzers were removed and repairs were made by the manufacturer. Protective shields will be added, and the analyzers relocated so that false readings will not be recorded if leakage occurs around the bypass damper. The analyzers will be reinstalled in their new locations during the plant outage next period.
 - Work continued on repairs to the variable frequency drive for the ID fan. Electrical safety devices and instrumentation

were installed so that the VFD can be restarted and calibrated during the plant outage. No additional problems are expected during restart.

- **Reactor Area** - All operating systems in the reactor area were checked and operated this period including:
 - Passing of hot flue gas through the activation reactor. No problems were encountered as a result of thermal expansion.
 - Blowdown and operation of the steam, condensate, water, and compressed air systems.
 - Startup, adjustment, and operation of the ash handling system. Only minor mechanical problems were encountered during startup. These problems will be resolved during the next period.
 - Checkout and calibration of all new instrumentation.

Environmental Monitoring (WBS 1.3.3)

The first phase of the Environmental Monitoring Plan (EMP) was implemented during this period with the following activities:

- **Compliance Monitoring** - Gaseous source sampling was performed to establish background emissions from Unit #2 and to determine compliance with RP&L's various permits.
 - Particulate levels were measured after the ID fan to determine emissions levels for Unit #2.
 - PM-10 monitoring could not be performed as intended after the ID fan because the test ports could not accommodate the size of a PM-10 probe. New test ports at this location are being installed for future monitoring.

- **Supplemental Monitoring** - Sampling of all three types of media, solid, aqueous, and gaseous, was performed as specified by the EMP to possibly identify any additional health and environmental impacts caused by the project. To this end, the following samples were taken:
 - Bottoms ash samples from the boiler were sent to an outside laboratory for analysis of Ph, sulfates, alkalinity, organics and TCLP.
 - Fly ash samples from the ESP area were taken and sent to an outside laboratory for the same analysis as the bottom ash.
 - Gaseous emissions were monitored after the ID fan for levels of CO and SO₂ in addition to the compliance monitoring requirements.
 - Wastewater discharges were sampled and tested for alkalinity.
- **Reporting** - Data collected on site and from outside laboratories has been analyzed and will be submitted to DOE under separate cover.

The next period of compliance and supplemental monitoring will occur during the parametric phase of LIFAC testing.

FUTURE PLANS

During the next reporting period, emphasis will be placed on the following activities:

- Resolve mechanical problems with the bypass damper.
- Reinstall the flue gas analyzers.
- Place the VFD in full operation and service.
- Resolve mechanical problems on the reactor ash handling system.
- Begin parametric testing.
- Submit all delinquent reports.
- Complete startup and checkout activities.
- Prepare the Baseline Test Report.